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Surface soil characterization of explosives and metals at the Land Force Central Area Training Centre (LFCA TC) Meaford, Ontario (Phase II) Final report

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Technical Report

DRDC Valcartier TR 2009-218

October 2009

Canada

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This work was sponsored by Director Land Environment and Director General Environment

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Abstract

This work describes the second evaluation of the impacts of the live fire training at the Land Force Central Area Training Centre (LFCA TC) Meaford, Ontario (Phase II). This study was conducted in August 2008 by DRDC Valcartier for Director Land Environment (DLE) to complete the evaluation of the soil contamination by explosives and metals. In parallel, the Institut national de la recherche scientifique (INRS) conducted sampling and analysis of surface water and groundwater for metals and explosives and produced two separate reports describing the results from their Phase I and II. In our study, most of the ranges at LFCA TC Meaford were sampled during the September 2007 campaign. In August 2008, nine ranges were sampled to complete our understanding of the explosives and/or metals contamination. More precisely, the Apeldorn grenade range was re-visited to confirm metal concentrations observed during Phase I, the Caen range was re-sampled to confirm propellant residues concentrations while Cambrai target positions were re-sampled to examine the high selenium concentrations found during Phase I. In Cassino, small arms target positions were evaluated for metal concentrations while the 40 mm impact area was evaluated for energetic concentrations. The urban assault portion of Ortona range was sampled for energetics while Normandy, Position 409 and the Gravel Pit were sampled for energetics and metals. Finally, it was not possible to sample the stop butt of the impact area. Forty one soil samples were collected and analysed, including 21 for energetic materials, 20 for metals and one for perchlorate analyses. The 20 soil background samples taken for the metals evaluation during Phase I served again for comparison purposes. Metal analyses were done using Inductively Coupled Plasma /Mass Spectrometry (ICP/MS) and explosives concentrations were determined using the High Pressure Liquid Chromatography (HPLC) Method EPA 8330b. The results confirmed that the firing positions of Caen are contaminated by nitroglycerine and 2,4-DNT. Surprisingly, the tank positions in Cambrai still highly contaminated by metals did not show selenium at extreme concentrations as in Phase I. Except for the firing positions in Caen, no energetic materials were detected in any of the samples collected. The Apeldorn grenade range still showed high zinc concentrations as for the Gravel Pit that showed many metal concentrations higher than the Canadian Council of Ministers of Environment (CCME) Industrial Soil Quality Guideline threshold criteria. This report describes the sampling and the results obtained during this study, examines the results obtained during both phases and proposes recommendations for the sustainability of the training areas.

Résumé

Ce travail décrit la seconde évaluation des impacts de l'entraînement de tir réel faite au Centre d'instruction du Secteur du Centre de la Force terrestre (CISCFT) à Meaford, en Ontario (Phase II). Cette étude a été effectuée en août 2008 par RDRC Valcartier pour le Directeur Environnement de l'armée de terre (DEAT) afin de compléter l'évaluation de la contamination des sols par les explosifs et les métaux. En parallèle, l'Institut national de la recherche scientifique (INRS) a effectué l'échantillonnage de l'eau de surface et de l'eau souterraine pour les métaux et les explosifs et produit deux rapports séparés décrivant les résultats de leurs phases I et II. Dans notre étude, la plupart des secteurs du CISCFT Meaford ont été échantillonnés pendant la campagne de septembre 2007. En août 2008, neuf secteurs ont été échantillonnés pour

compléter l'évaluation de la contamination par les explosifs et/ou par les métaux. Plus précisément, le secteur de grenade Apeldorn a été revisité pour confirmer les concentrations en métaux observées durant la phase I, le secteur Caen a été rééchantillonné pour confirmer les concentrations de résidus de propulsifs pendant que les positions des cibles de Cambrai ont été rééchantillonnées pour examiner les concentrations importantes de sélénium observées durant la phase I. Dans Cassino, les positions des cibles de petit calibre ont été évaluées pour les concentrations en métaux tandis que l'aire d'impact des munitions de 40 mm a été évaluée pour les concentrations en matériaux énergétiques. La portion d'assaut urbaine d'Ortona a été échantillonnée pour les énergétiques alors que Normandy, la position 409 et la réserve de pierre concassée ont été échantillonnées pour les concentrations en matériaux et en métaux. Finalement, il n'a pas été possible d'échantillonner la butte d'arrêt de la zone d'impact. Quarante et un échantillons de sol ont été recueillis et analysés, incluant 21 pour les matériaux énergétiques, 20 pour les métaux et un pour les perchlorates. Les 20 échantillons de sols d'arrière-plans recueillis durant la phase I ont servi de nouveau pour analyser les métaux et servir de comparaison. Les analyses de métaux ont été effectuées par plasma inductif couplé/spectrométrie de masse (PIC/SM) et les concentrations d'explosifs ont été déterminées par la méthode de chromatographie liquide haute pression (CLHP) EPA 8330b. Les résultats ont confirmé que les positions de tir de Caen sont contaminées par de la nitroglycérine et du 2,4-DNT. Étonnamment, les positions des chars d'assaut dans Cambrai toujours très contaminées par des métaux n'ont pas montré les concentrations importantes de sélénium observées durant la phase I. À l'exception des positions de tir dans Caen, aucun matériau énergétique n'a été détecté dans aucun des échantillons ramassés. Le secteur de grenade Apeldorn a encore montré des concentrations de zinc élevées ainsi que le secteur de pierre concassée qui a montré des concentrations à des valeurs supérieures au critère de niveau industriel pour les risques à la santé humaine du Conseil canadien des ministres de l'Environnement (CCME) pour plusieurs métaux. Ce rapport décrit l'échantillonnage utilisé ainsi que les résultats obtenus durant cette étude, examine les résultats obtenus durant les deux phases et propose des recommandations pour le développement durable de ces aires d'entraînement.

Executive summary

Surface soil characterization of explosives and metals at the Land Force Central Area Training Centre (LFCA TC) Meaford, Ontario (Phase II) Final report:

Guy Ampleman; Sonia Thiboutot; André Marois; Annie Gagnon; DRDC Valcartier TR 2009-218; Defence R&D Canada – Valcartier; October 2009.

Introduction or background: The international context of demilitarization, the closure of military bases and the more stringent aspects of environmental laws have led to the establishment of new areas for research and development. Many activities of the Canadian Forces such as the firing of ammunition and the destruction of obsolete ammunition by open burning and open detonation may lead to the dispersion of energetic compounds and other munitions-related contaminants in the environment. It is within this context that Defence Research and Development Canada - Valcartier (DRDC Valcartier) and the US Army Engineer Research and Development Center (ERDC), Cold Regions Research and Engineering Laboratory (CRREL) and the ERDC Environmental Laboratory (EL) initiated research programmes to study the environmental impacts of energetic materials that are found in ammunition. The site characterization allowed the development of a unique expertise and positioned our departments to better understand the impacts of live fire training and to be in a readiness state to answer any inquiries and take corrective actions, if needed. The first training areas to be characterized were mainly army bases such as CFB Chilliwack, Shilo, Valcartier, Gagetown in Canada and, Fort Bliss, Fort Lewis, Yakima, MMR and many others in the United States. The Canadian programme was sponsored by DRDC, DGE, DLE and by a major US Department of Defense (DoD) funding program, the Strategic Environmental R&D Program (SERDP). Considering that LFCA TC Meaford will be extensively used in the future, DRDC Valcartier was tasked by Director Land environment (DLE) to evaluate the contamination by explosives and metals in soils of the ranges in Meaford. At the same time, the Institut national de la recherche scientifique (INRS) conducted surface water and groundwater sampling for explosives and metals analyses and produced separate reports describing their findings.

Results: Most of the ranges at LFCA TC Meaford were sampled during the September 2007 campaign. In August 2008, nine ranges were sampled to complete our understanding of the explosives and/or metals contamination. More precisely, the Apeldorn grenade range was re-visited to confirm metal concentrations observed during Phase I, the Caen range was re-sampled to confirm propellant residues concentrations while Cambrai target positions were re-sampled to examine the high selenium concentrations found during Phase I. In Cassino, small arms target positions were evaluated for metal concentrations while the 40 mm impact area was evaluated for energetic concentrations. The urban assault portion of Ortona range was sampled for energetics while Normandy, Position 409 and the Gravel Pit were sampled for energetics and metals. Forty-one soil samples were collected and analysed, including 21 for energetic materials, 20 for metals and one for perchlorate analyses. The results confirmed that the firing positions of Caen are contaminated by nitroglycerine and 2,4-DNT. Surprisingly, the tank positions in Cambrai still highly contaminated by metals did not show selenium at extreme concentrations as in Phase I. Except for the firing positions in Caen, no energetic materials were detected in any of the samples

collected. The Apeldorn grenade range still showed high zinc concentrations as for the Gravel Pit that showed many metal concentrations higher than the Canadian Council of Ministers of Environment (CCME) Industrial Soil Quality Guideline threshold criteria.

Significance: These results indicated that live firing and training activities may lead to the contamination of soils by explosives and metals at significant concentrations. Nevertheless, the Meaford training area is now considered not contaminated and may be used for training purposes. An important aspect of training area characterization is the water surveillance programme that will be put in place following the hydrogeological study. The public has very low acceptance for water contamination by explosives and metal concentrations in water are strictly regulated. It is therefore of high significance to conduct these characterizations and understand the explosives and metal contamination on the Canadian Forces bases.

Future plans: Recommendations will be made and actions taken to remediate areas that were impacted by metals or energetic materials. A surveillance program will be established to monitor the quality of groundwater and surface water.

Sommaire

Surface soil characterization of explosives and metals at the Land Force Central Area Training Centre (LFCA TC) Meaford, Ontario (Phase II) Final report:

Guy Ampleman; Sonia Thiboutot; André Marois; Annie Gagnon; DRDC Valcartier TR 2009-218; R & D pour la défense Canada – Valcartier; Octobre 2009.

Introduction ou contexte: Le contexte international de la démilitarisation, de la fermeture de bases et de la sévérité croissante des lois environnementales a entraîné l'émergence de nouveaux champs de R et D. Plusieurs activités des Forces canadiennes, telles que l'entraînement au tir de diverses munitions et la destruction de munitions par brûlage ou détonation extérieure peuvent conduire à la dispersion de matériaux énergétiques et d'autres contaminants dans l'environnement. C'est dans ce contexte que Recherches et développement pour la défense Canada - Valcartier (RDDC Valcartier) en collaboration avec Cold Regions Research and Engineering Laboratory (CRREL) et Environmental Laboratory (EL) de l'US Army ERDC, ont entrepris des programmes de recherches afin d'étudier les impacts environnementaux des composés énergétiques que l'on retrouve dans les munitions. La caractérisation des sites a permis de développer une expertise unique et a positionné nos organisations de façon à mieux comprendre les impacts des entraînements au tir réel et à être prêtes à répondre à toutes les éventualités pour prendre des mesures correctives, si nécessaire. Les premiers sites d'entraînement à être évalués ont été des bases de l'armée, telles que BFC Chilliwack, Shilo, Valcartier, Gagetown au Canada et Fort Bliss, Fort Lewis, Yakima, MMR et plusieurs autres aux États-Unis. Le programme canadien a été financé par RDDC, DGE, DEAT ainsi que par un programme majeur de fonds américains, le Strategic Environmental R&D Program (SERDP). Compte tenu que CISCFT Meaford sera davantage utilisé dans le futur, RDDC Valcartier a été mandaté par le Directeur Environnement de l'armée de terre (DEAT) pour évaluer la contamination par les explosifs et les métaux dans les sols des secteurs à Meaford. En même temps, l'Institut national de la recherche scientifique (INRS) a effectué l'échantillonnage de l'eau de surface et souterraine pour les métaux et les explosifs et produit des rapports séparés décrivant ces résultats.

Résultats: La plupart des secteurs du CISCFT Meaford ont été échantillonnés pendant la campagne de septembre 2007. En août 2008, neuf secteurs ont été échantillonnés pour compléter l'évaluation de la contamination par les explosifs et/ou par les métaux. Plus précisément, le secteur de grenade Apeldorn a été revisité pour confirmer les concentrations en métaux observées durant la phase I, le secteur Caen a été rééchantillonné pour confirmer les concentrations de résidus de propulsifs pendant que les positions des cibles de Cambrai ont été rééchantillonnées pour examiner les concentrations importantes de sélénium observées durant la phase I. Dans Cassino, les positions des cibles de petit calibre ont été évaluées pour les concentrations en métaux tandis que l'aire d'impact des munitions de 40 mm a été évaluée pour les concentrations en matériaux énergétiques. La portion d'assaut urbaine d'Ortona a été échantillonnée pour les énergétiques alors que Normandy, la position 409 et la réserve de pierre concassée ont été échantillonnés pour les concentrations en matériaux énergétiques et en métaux. Quarante et un

échantillons de sol ont été recueillis et analysés, incluant 21 pour les matériaux énergétiques, 20 pour les métaux et un pour les perchlorates. Les résultats ont confirmé que les positions de tir de Caen sont contaminées par de la nitroglycérine et du 2,4-DNT. Étonnamment, les positions des chars d'assaut dans Cambrai toujours très contaminées par des métaux n'ont pas montré les concentrations importantes de sélénium observées durant la phase I. À l'exception des positions de tir dans Caen, aucun matériau énergétique n'a été détecté dans aucun des échantillons ramassés. Le secteur de grenade Apeldorn a encore montré des concentrations de zinc élevées ainsi que le secteur de pierre concassée qui a montré des concentrations à des valeurs supérieures au critère de niveau industriel pour les risques à la santé humaine du Conseil canadien des ministres de l'Environnement (CCME) pour plusieurs métaux.

Importance: Ces résultats indiquent que le tir réel et les activités d'entraînement peuvent entraîner la contamination des sols par les explosifs et les métaux à des concentrations importantes. Néanmoins, la zone d'entraînement de Meaford est désormais considérée comme non contaminée et peut être utilisée pour l'entraînement. Un aspect important de la caractérisation des secteurs d'entraînement et de l'eau souterraine est la mise en place d'un programme de surveillance suite à l'étude hydrogéologique. La population accepte difficilement la contamination de l'eau souterraine par des explosifs et les concentrations de métaux dans l'eau sont strictement réglementés. Il est donc de la plus haute importance de procéder à ces caractérisations et de comprendre la contamination par les explosifs et les métaux sur les bases des Forces canadiennes.

Perspectives: Des recommandations seront faites et des mesures seront prises pour nettoyer les aires contaminées par les métaux et les explosifs. Un programme de contrôle sera mis en place pour surveiller la qualité de l'eau souterraine et de surface.

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Acknowledgements

The authors wish to thank the Director Land Environment and Director General Environment for their financial support and vision. The authors also wish to thank Defence Construction Canada (DCC) for their support during this surface characterization. More precisely, the authors wish to acknowledge the excellent work performed by Ms. Grace Harrison from DCC who was responsible for all of the analytical supplies and metal analyses during the field work in Meaford. Range Control Canadian Forces personnel of LFCA TC Meaford are especially thanked for their invaluable help, openness, description of the ranges and support in all these sampling events. More precisely, we would like to thank Mr. Ted Keunecke, the Environmental Officer, who gave us all the support and provided references needed to accomplish our task. We also wish to thank all personnel of range control at the LFCA TC Meaford who helped us, more particularly the Explosive Ordnance Disposal personnel, Mr Elmer Gallant.

1 Introduction

During the last decade, many needs emerged related to the energetic contaminants dispersed by munitions, or present in explosives dumps, trials or destruction fields, firing areas and production sites. Within this context of environmental awareness, Defence Research and Development Canada, through DRDC Valcartier, has directed some of its resources to assess and develop expertise related to the environmental risks associated with explosive compounds. Metallic debris also represents an important issue for the Department of National Defence (DND) since live firing of munitions is spreading significant quantities of metals that are strictly regulated by law.

Many Canadian Forces sites were highly suspected of being contaminated with energetic substances as described in the literature (Refs. 1-14). To evaluate the contamination of DND sites, sampling and characterization of various ranges were performed over the last 15 years (Refs. 1, 2, 13-16). A protocol was developed and describes the different methods of sampling and the analytical chemistry (Ref. 17). This protocol was updated in collaboration with the US Army Corps of Engineers, Cold Regions Research and Engineering Laboratory (CRREL) and reviewed under the auspices of the Technical Cooperation Program (TTCP) by the member nations (Canada, U.S., U.K., Australia and New Zealand) in a key technical area (KTA 4-28) (Ref. 18). The last version of this protocol can be found on the web at: <http://www.em-guidelines.org/ener.htm>. Up to now, research has demonstrated that explosives are not common contaminants, since they exhibit limited aqueous solubility and are dispersed in a heterogeneous pattern of contamination. In Canada and in the United States, many efforts were made to develop the analytical chemistry, the best sampling procedure and to understand the complex fate of explosives in the environment (Refs. 3-12, 18-27).

DRDC Valcartier collaborated with CRREL and the US Army Corps of Engineers, Environmental Laboratory (EL) in Vicksburg to evaluate the environmental impacts of live-fire training, to characterize and mitigate adverse effects on training ranges and thereby sustain the military activities (Ref. 28). Lately, more efforts were undertaken to assess the environmental loading of explosives at most of the Canadian Forces Bases (CFB). To date, these efforts addressed mainly heavily used target areas (Refs. 13-16, 29-40). Walsh et al (Ref. 10) observed that the firing positions were also experiencing a build-up of energetic residues, and since then, a lot of studies have been dedicated to the characterization of the firing positions (Refs. 39, 41). It was determined that NG and/or 2, 4-dinitrotoluene (2,4-DNT) embedded in nitrocellulose fibres are deposited in front and around firing positions (Refs. 31, 40-42).

Following that, DRDC Valcartier assessed the dispersion of propellant residues following 105-mm artillery and tank gun firings at CFB Valcartier by placing aluminium witness plates in front of the muzzles of the guns (Ref. 43). At CRREL, similar trials were conducted using snow as a collection media (Ref. 44). Both studies demonstrated that propellant residues comprised of nitrocellulose fibres containing 2,4-DNT were deposited in front of the muzzle of artillery guns but no residues were found after firing tank ammunition in Valcartier (Ref. 43). More recently, Ampleman et al. confirmed that 0.2 - 0.5% of 2,4-DNT is ejected at the muzzle of the gun during artillery firings in open atmosphere and inside a muffler in Nicolet (Ref. 45). Ampleman et al. confirmed that tank gun firing resulted in no residues expelled by the 105 mm gun (Ref. 46). This was explained by the fact that 105 mm tank gun munitions contained more propellants than the 105 mm artillery gun munitions reaching a higher pressure and temperature in the tank gun,

leading to a better combustion. More recently, Walsh et al. studied residues at mortar firing positions (Ref. 47) and NG was found at elevated concentrations for 81-mm mortars. Thiboutot et al. also found that firing shoulder weapons such as the Karl Gustav 84 mm may leave up to 14% of nitroglycerine at the firing positions (Ref. 48). In February 2009, Ampleman et al. performed a tank trial at CFB Valcartier using a better collection system and they also used the snow cover in collaboration with CRREL to catch the propellant residues. It was found that tank firing with the 105 mm gun spread 0.2% of 2,4-DNT and this was confirmed by the two separate ways of measurements. This report will soon be written and made available. Now, more efforts are dedicated at sampling firing positions for all military activities.

To better assess the contamination and characterize an area, an appropriate definition and understanding of the hydrogeological context of the site is required. Characterizing the groundwater quality, especially on large ranges, is critical because metals and energetic materials are mobile in sandy environments and may migrate in groundwater, presenting a threat to human health and to the environment. Groundwater flow has to be carefully assessed by determining its velocity and direction. The quality of the groundwater also has to be evaluated since it is often used for irrigation purposes, as a drinking water source by the base and to sustain aquatic ecosystems. In LFCA TC Meaford, groundwater discharges into Georgian Bay, a highly sensitive area for wildlife and human receptors. The first phase of the hydrogeological study was completed to catch the propellant residues by INRS in September 2007 and all the results from this study were reported (Ref. 49). The second phase of the hydrogeological study took place in June-September 2008 and the report will include the drilling of new wells.

This report describes the strategy used in the sampling and the results obtained during the surface soil sampling study that was conducted in August 2008 and called Phase II. It will also incorporate the evaluation of results from both Phase I and II and will make recommendations to mitigate or remediate the impacts of the contamination by metals and explosives. This study was performed by DRDC Valcartier for the Director Land Environment who sponsored the entire study. Defence Construction Canada (DCC) was responsible for hiring the analytical laboratory, providing manpower, logistics and making the link with range control personnel.

2 Experimental

2.1 Contractors Involved

Defence Construction Canada (DCC) was responsible for hiring the analytical laboratory and for supplying all of the analytical tools, solvents, bottles, etc., for the analyses of metals. They were also responsible for making the link between DRDC Valcartier and range control and other responsible personnel at LFCA TC Meaford. DCC was also responsible for the shipment of all samples to the laboratories. The analytical work for metals was sub-contracted to ALS Laboratory Group, Analytical Chemistry and Testing services, Environmental Division in Mississauga, Ontario. All the energetic materials analyses were performed by DRDC Valcartier which provided the coolers and materials for this sampling.

2.2 Sample Handling and Treatment

Explosives are not volatile compounds and therefore, no specific precautions such as the use of sealed containers had to be taken during sampling of media containing explosives. Soil samples were composited based on a minimum of 40 systematic sub-samples and were stored in polyethylene bags. The bags were immediately stored on ice in coolers in the dark to avoid photodegradation of light-sensitive compounds. The use of polyethylene bags decreased the space needed for storing samples. Each day, the soil samples were transferred from the coolers to a refrigerator at -20°C and kept there until the last day before shipping. They were brought frozen in coolers by INRS to DRDC Valcartier. The soil samples that were analysed for metals were kept in the same manner until shipped by DCC to ALS Laboratory for digestion and analysis.

2.3 Parameters Monitored and Analytical Methods

Some soil samples were analysed for metals and others for energetic materials. A total of 41 soil samples were collected including 21 for energetic materials, 20 for metals and one for perchlorate analyses. Metals were analysed by Inductively Coupled Plasma/Mass Spectrometry (ICP/MS) by ALS Laboratory. Most of the metal parameters available by this method were included in the study. During Phase I, 32 metal parameters were analysed by Maxxam Analytical Inc while for Phase II, only 18 metal parameters were analysed by ALS Laboratory.

For soils, energetic materials were analysed at DRDC Valcartier using the Reverse Phase High Pressure Liquid Chromatography (RP-HPLC) USA EPA SW 846 Method 8330b, a method that can produce a 0.1 ppm detection limit. See the EPA Method 8330b found on their Internet site (www.epa.gov) for a complete description of the HPLC method. The HPLC method was preferred over the Gas Chromatography/Electron Capture Detection method recently published since reproducible results with the GC/ECD method were difficult to achieve (Refs. 24-25). In our study, the HPLC method gave a detection limit of 0.1 ppm for all analytes in the calibration curve and this detection limit was reduced to 0.02 ppm when the sample extracts were concentrated in a Zymark apparatus.

Soil samples were dried in a hood for 24 hours in the dark, homogenized by adding acetone to form a slurry which was then evaporated. Soils were sieved through 10-mesh sieves and extracted at DRDC Valcartier according to the following procedure. Ten grams of soil were put into an amber glass vial and mixed with acetonitrile (20 mL). A vortex was applied for one minute, followed by a sonication period of 18 hours in a cooling ultrasonic bath in the dark. The samples were left to settle for 30 minutes. Acetonitrile (2 ml) was decanted from the vial and diluted with water (2 ml) containing calcium chloride (1%). The solution was filtered on a 0.45-micron filter to get 1 ml of solution ready to inject into the HPLC.

Soil extracts were maintained at 4°C until analyzed by HPLC according to Method EPA 8330b. Analyses were performed with a HPLC Agilent HP 1100 equipped with a degasser G1322A, a quaternary pump model G1311A, an autosampler G1313A and a UV diode array detector model G1315A monitoring at 210, 220 and 254 nm. The injection volume was 20 µl and the column was a Supelcosil LC-8 (25 cm x 3 mm x 5 µm) eluted with 15:85 isopropanol/water (v/v) at a flow rate of 0.75 ml/min. The column temperature was maintained at 25°C during the analysis. Standards and solvents were diluted 1:1, acetonitrile to water (0.5 ml Acn /0.5 ml water). When 10 g in 20 ml of acetonitrile were used for the soil extraction, the detection limit for this method was 0.100 ppm.

In order to obtain a lower detection limit at 0.02 ppm, we filtered and concentrated to dryness 10 ml of acetonitrile from the soil extract with a Zymark evaporator (model TurboVap LV) in a test-tube. Thereafter, we added 0.5 ml of water and 0.5 ml of acetonitrile and used this mixture as the extract to inject for the analysis. All the soil extracts that did not show concentrations of energetic materials were re-injected after the treatment to the Zymark and these samples were assigned lab number with a “z “ as seen in the tables.

2.4 Sample Nomenclature

All soil samples were named according to the following labelling system:

First part: sample type

M-07:	Meaford sampling campaign 07
M-08:	Meaford sampling campaign 08

Second part: Location by range or type

BG:	Background sample
UA:	Urban Assault of Ortona
NORM:	Normandy

CAM:	Cambrai
CAEN :	Caen
CAS :	Cassino
AGR:	Apeldorn grenade
P409:	Position 409
GP:	Gravel Pit

Third part: Identification of the sample source

Position number (ex. 1, 2 or 1-3)

Background location by number or

Type of sample (ex. T1 for Tank 1) or

Firing positions (ex. FP 100m)

Fourth part: Identification of the sample

According to sampling strategy or position number on figures (ex. 0-5m in front of pad) or DUP for duplicate

2.5 QA/QC

Quality assurance and quality control programs were included in this study. Background soil samples were collected outside ranges close to the roads surrounding the ranges during Phase I and were used again in Phase II to serve as comparison. All these background samples were collected to get the most representative soil types in areas close to the ranges. Analyses were done twice for energetic materials (lab replicates). A mean for the energetic results was calculated. One field replicate in Cambrai was also sent for analysis and was named duplicate for comparison. The contracted laboratory reported their QA/QC including surrogates and blanks, detection limits, and quantification limits. Trip blanks and field blanks were also included in the QA/QC plan.

2.6 Safety and Emergency Plan

The sampling of an UXO-contaminated area represents an increased level of risk for personnel. The Range Control Officers gave a safety briefing to people involved in the sampling program. This briefing explained the precautions to be taken to avoid contact with UXOs and also

described the various types of UXOs that may be found on ranges. A safety and emergency plan was also put in place for any incident that could have occurred while sampling. This plan was under the responsibility of the LFCA TC Meaford Range Control unit. When on site for sampling, personnel were always accompanied by Range Control personnel who were equipped with radios to contact Range Control in case of an emergency.

2.7 Sampling Strategy

Background soil samples are critical to establish the anthropogenic contribution versus the natural contribution for all metal parameters. During Phase I, background composite samples were collected randomly, in circles of approximately 10 metres in diameter in different locations outside the ranges close to the roads. A minimum of 30 sub-samples were collected to form each background sample. A statistical analysis was conducted to identify a mean background concentration and to define a limit for a value that can be considered normal. Values at the extremities of the lognormal curve were identified. The limits were chosen for a probability of 97.72% (two times the standard deviation). The probability of finding a result with a value higher than this limit is 2.28 %. When the metals were not detected, a value at half of the detection limit was used for the data analysis. Instead of re-sampling more background samples during Phase II, all the results from the background samples collected during Phase I were used as a comparison for the metal analyses of Phase II, saving time and funds. Since they represent the geology of the site, it made perfect sense to proceed this way.

The usual strategy for soil sampling was based on multi-increment systematic sampling around representative areas of each range. Usually, surface soils were collected at a depth of 0-5 cm. This strategy was used in previous studies on antitank ranges, which showed very distinct patterns of contamination around targets (Ref. 2). This strategy was used for all samples. In Apeldorn grenade range, the linear transect strategy was used to collect soils in front of the bunker. This strategy was applied during Phase I and we used the same strategy to verify the pattern of dispersion of energetic materials in front of the bunker and to be able to compare the results between the two Phases. The GPS locations were collected in most of the ranges and can be found in Table 1. Some GPS locations will be mentioned during the analysis of the results. Sampling specific to each range will be described in the results and discussion section.

3 Results and Discussion

In our evaluation of the results for the metals concentrations, we chose to compare values for each parameter to values encountered in the background samples. By doing so, we can evaluate if the concentrations of a particular contaminant is anthropogenic or not. GPS locations for each background sample can be found in Table 1. From the management point of view, this approach can be valuable, but the site owners want to know if there are problems, at which extent and what can be done to solve them. Scientifically, comparison with the background values is important since it allows the understanding of the first effects of the training activities on the environment and gives us plenty of time to react and possibly eliminate the effects of such activity by applying mitigation methods to the sources.

Our approach consisted in comparing all the results to background values first, then to the agricultural soil quality guidelines (ASQG) and finally to the Industrial Soil Quality Guidelines (ISQG) established by the Canadian Council of Ministers of the Environment (CCME) (see www.ccme.ca or the file annexed in Annex A on compact disk). Even if DND properties are not dedicated to agriculture, the ASQG represents the first official threshold value and if concentrations of a particular parameter are higher than the ASQG, this can raise important questions for the management of the sites. This was particularly true for sites such as WATC Wainright where cows were allowed to graze on DND property during the summer. The same rationale can be applied to the ISQG since DND properties are not industries, but having concentrations higher than the ISQG can urge the Department to find and apply solutions for due diligence.

In our evaluation of the results, the mean values for background samples were the mean of all collected backgrounds for each parameter measured. When results lower than detection limits were encountered for specific parameters, half of the detection limit for that parameter was used for calculation of the mean value. The results obtained in training areas were compared to the mean value of the background to which was added twice the standard deviation. This allowed the selection of results having values greater than the background means, while being representative. Results are presented for each parameter instead of per sample to facilitate the analysis of trends for each parameter. Backgrounds were always tabulated first with mean, standard deviation, mean plus twice the standard deviation, and CCME threshold criteria values for each metal. Then, results for samples collected in the training areas were tabulated. As already mentioned, we used the values obtained from the background samples collected during Phase I for the need of comparison with the Phase II results.

For metals that were not included in the CCME list, results were compared only to the mean values added to twice the standard deviation of all soil background samples. Such results exceeding this value were highlighted in blue in Tables 2-6. When metal concentrations were above the agricultural criteria, they were also compared to the industrial soil criterion, which is the most permissive criterion. When the values were above the agricultural but below the industrial criterion, they were highlighted in green. When above the industrial criterion, the values were highlighted in red in the tables.

During Phase I, 135 soil samples were collected including 79 for energetic materials, 56 for metals and seven for PAHs analyses. Analyses for the following metals were conducted on the 56

soil samples: Al, Sb, As, Ba, Be, Bi, B, Ca, Cd, Cr, Co, Cu, Fe, Pb, Li, Hg, Mg, Mn, Mo, Ni, K, Se, Sr, Na, Ag, Ti, Tl, W, Sn, U, V, and Zn. Sampling for metal analyses was accomplished in nine out of the 17 ranges visited. This included: Apeldorn grenade range, Cambrai, Fibua on Ortona, Gravenstafel Ridge, Urban Assault, Paardeburg Anti-Tank, Gully, Alpha small arms range, and the Skeet range. No major environmental impacts related to the training activities were identified in these ranges. In soils, the accumulation of some heavy metals associated with ammunition was observed in some parts of ranges and on some occasions, concentrations were above the industrial criterion. Phase I results clearly demonstrated some problems associated with soil contamination and some of these soils were re-sampled during Phase II to better understand the situation.

In Phase II, as mentioned, only 18 metal parameters were analysed by ALS Laboratory and these metals in soils were: Sb, As, Ba, Be, B, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, Tl, V and Zn. Compared to Phase I metal analyses, Al, Bi, Ca, Fe, Li, Mg, Mn, K, Sr, Na, Ti, W, Sn, and U are missing. By examining Phase I metal analyses results in tables of Reference 50, it is found that for Al, Bi, Fe, Mg, Sr, Na, Ti, W and U some results are highlighted in blue with values most of the time less than double the mean background plus twice the standard deviation. Furthermore, there are neither ASQGL nor ISQGL values for any of these parameters and consequently, there is no law regulating these metals. The fact that they were not analysed during Phase II does not hinder the understanding of the situation in Meaford. For Ca, Li, Mn and K, it is the same situation, there are neither ASQGL nor ISQGL values for these parameters and moreover, these metals did not exhibit values higher than the BGL in Phase I.

For the 21 soil samples analysed for energetic materials, 13 parameters were screened for explosives, including the most common explosives RDX, HMX and TNT, using the HPLC method. Analyses for energetic materials were done at DRDC Valcartier using the RP-HPLC EPA SW 846 Method 8330b with a detection limit of 100 ppb for most analytes except for DNB, tetryl and PETN, for which limits were slightly higher. When concentrations were low, we used a Zymark concentrator to lower the detection limit to 20 ppb. Most of the analyses were performed twice and reproducible results were observed indicating that our sampling methods and analytical chemistry was good. Most of the samples were done using the Zymark concentrator to detect all the analytes at lower concentrations except for the Caen firing positions that contained measurable nitroglycerine and 2,4-DNT. These samples are identified by a “z” at the end of the lab number.

For the purposes of this report, we can consider that energetic compounds fall into two classes, those that are related to propellants and those related to high explosives. Nitroglycerine (NG), dinitrobenzene (DNB), dinitrotoluene (DNT) and trinitrobenzene (TNB) are either major ingredients or impurities in various types of propellants such as those used in rocket motors. Usually, rockets use either double base propellants composed of nitrocellulose and nitroglycerine or a thermoset polymeric matrix based on hydroxyl-terminated polybutadiene containing ammonium perchlorate as the oxidizer. The single base propellants also contain DNT as a plasticizer. Impurities such as DNB and TNB coming from photodegradation of TNT or coming from the synthesis of energetic materials that started from toluene containing benzene as an impurity may be found in explosives.

Perchlorate analysis was performed only for one sample in Gravel Pit since they usually burn flares and other pyrotechnics products at this site. High explosives used by both Canada and the

United States generally contain either TNT (2,4,6-trinitrotoluene) or mixtures of TNT with RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), or for some older munitions, tetryl. Most of the air weapons contain TNT with aluminium (triton explosives). The most powerful weapons contain Composition B (TNT with RDX) or octol (TNT with HMX). When UXOs are found on sites, they are often blown in place (BIP) using C-4, a mixture of RDX with a polymer. These BIP operations often spread explosives into the environment (Ref. 11). On top of the most common explosives, the HPLC method can detect the metabolites and impurities of TNT such as the 4-ADNT, 2-ADNT, nitrobenzene, etc. Results for energetic materials in soil samples are presented in Tables 5 and 6. 2-aminodinitrotoluene and 4-aminodinitrotoluene, 1,3-dinitrobenzene, 2-, 3-, and 4-nitrotoluene, 1,3,5-trinitrobenzene and tetryl were removed from Table 6 since they were never detected in any samples. In fact, except for the propellant residues detected in Caen, no energetic materials were detected in any of the samples collected during Phase II.

3.1 Apeldorn Grenade Range

As for most of the grenade ranges, the Apeldorn grenade range was composed of a bunker and a flat area in front of the bunker where grenades are launched to explode (Fig. 1). Normally, this area is contaminated by energetic materials and metals, so the soil samples were collected during Phase I for both metals and EM analyses. Seven samples were composited in front of the bunker at distances of 5, 10, 15, 20, 25 and 30 metres (Fig. 2) and were named M-07-AGR-0-5m, M-07-AGR-5-10m, etc. to analyse the pattern of dispersion of metals in front of the launching bay. We re-collected soil samples using the same strategy during Phase II to compare and validate the dispersion of metals at this site. Since the explosive concentrations determined during Phase I were typical of grenade ranges and very low, no energetic materials analyses were done on soils collected during Phase II at that site. The main conclusion drawn for this site during Phase I was: “At this level, this site is not considered contaminated by energetic materials but the zinc presence must be further investigated”.

As described in Phase I, Cr, Pb, Mg, Ni, Ti, and Ba concentrations were higher than the BGL + twice the standard deviation (highlighted in blue) while Cu showed one value over the BGL and another one higher than the ASQGL highlighted in green in the area 10-15 m. Fortunately, this is the area where the duplicate sample was collected and this one showed only 22 ppm, a value below the BGL. On the other hand, Zn was found at values higher than the Industrial threshold criteria and this, for all samples. Concentrations for zinc varied from 988 to 2140 ppm that is 2.7 to 6 times higher than the CCME industrial threshold criteria. If one examines Tables 2-4, the metal concentrations observed during Phase II are similar to the concentrations of problematic metals observed in Phase I. The most important result is the fact the zinc concentrations were confirmed by Phase II at the same levels that were observed during Phase I from 605 to 1720 ppm, values almost 5 times higher than the ISQGL threshold criteria. The concentrations of zinc are distributed over the entire area sampled with maximum values in front of the bunker down to the 25 m line. The concentration seems to lower around the 25-30 m indicating probably the beginning of the end for the contamination. If one examines the results described in the INRS Report (Ref. 49), no energetic materials were found in any of their water samples and problematic metals in the surface soils of the grenade range were not mentioned in any of their water analyses. We may conclude that the metals found in surface soils had not migrated yet to the groundwater. INRS Phase II report will examine more thoroughly this situation.

3.2 Cambrai Range

Cambrai is very similar to Dieppe and Caen ranges and served as firing positions for many types of weapons such as: 105 mm Leopard tank, LAV Cougar 76 mm, Grizzly for 25 mm medium calibre, 105 mm Howitzer artillery gun, mortars, etc. These ranges are facing the impact area and at the end of the range, there is a large stop butt. They are all located around the observation tower where shooting can be observed (Fig. 3). In Cambrai, there are two tanks that are used as targets where important concentrations of selenium were found around the tanks during Phase I. Soil samples were re-collected to verify the concentrations of metals around the tanks during Phase II.

Metal analyses were done only around the tanks (Fig. 4). If we look at Tables 2-6 of Reference 50, Cr, Cu, Ag, Sr, Ti, W, U, Ba, Bi and B concentrations were above the BGL and indicated an anthropogenic accumulation. Most of these metals had concentrations well below the ISQGL. Sr, W and Bi were well over the BGL but there are no threshold criteria for these metals. Boron concentration was close to the ASQGL and thallium was close to the ISQGL. Uranium was also found at values higher than the BGL possibly indicating past uses of depleted uranium weapons. Hg, Mo, Se, As, Sn, Zn and Cd demonstrated concentrations higher than the ASQGL or the ISQGL. All the samples collected around both tanks showed Se, As, Zn and Cd at values higher than the ISQGL with selenium at extremely high concentrations of 9,020 and 33,200 ppm around the tanks. Zinc concentrations were also quite high at 2,320 and 994 ppm for T1 and T2.

In Cambrai, during Phase II, samples were collected in front of the tanks using a half circle surface, Tank 1 being the closest to the firing positions. Samples collected just in front of the tanks were named A and B and they represent the same surface. They are not duplicate samples since they were collected by two different persons using the same multi-increment sampling technique. If our sampling method is appropriate, we should find the same results for these samples. Another sample, named C, was collected in front of each tank using the half circle method at 3 m in front of the tanks. For Tank 2, another sample was collected at 10 m in front of the tank and was named sample D, a duplicate sample was collected for that Tank 2 sample.

During Phase II, soil samples were re-collected mainly to confirm these results especially for the selenium. If one examines Tables 2-4, it can be seen that there are some differences between concentrations observed in both phases. Cr, Hg, V and Ba were observed at concentrations over the BGL while Co, Cu, Pb, Sb, Ni, Se, Ag, As, Tl, Zn, and Cd were observed at concentrations higher than the ISQGL. It was found that selenium did not show concentrations as high as in Phase I while Hg showed also lower concentrations. These differences may come from the sample treatment as different laboratories may use a different sample treatment. During Phase II, the sampling was done with more precautions and soils were collected using the strategy of half circle in front of the tanks (Fig. 5).

Samples A and B collected by two different persons showed similar results for all parameters demonstrating that the multi increment sampling method works well. Curiously, Tank 2 is more contaminated than Tank 1 even if Tank 1 is closer to the firing positions and this for all distances and all parameters. The concentrations of metals such as lead, antimony and copper are way above the ISQGL with concentrations up to 1000 times the ISQGL. These are very high concentrations that will have to be dealt with because they could lead to serious problems. There

are no data for the groundwater available for this part of the range in Reference 49. Recommendations will be made in the next section about this site.

3.3 Normandy Range

This range is used for mortar firings mainly 66 mm mortars. On the range, there were four firing positions where mortars were installed. In front of the firing positions, there was a berm 1 km away and this berm was not sampled during Phase I. Normally, trainers installed the launcher behind the wooden wall and fired from there towards the berm (Fig. 6). In Phase I, soil composite samples were collected behind these wood structures for each of the firing positions. Nitroglycerine was found at concentrations ranging from 0.18-0.72 ppm. 2,4-DNT was also found at 0.07 and 0.08 ppm.

In Phase II, samples were collected at the target berm that was separated in two equal parts and were named left and right. Analyses for energetic materials and metals were done on each of these samples. Furthermore, at the firing positions, there was a misfire pit where munitions were destroyed, that was also sampled for energetic materials. Neither the berm nor the misfire pit showed energetic materials. The berm showed Pb, Sb, Tl, and Cd at concentrations higher than the BGL. Only one concentration higher than the ASQGL was observed for lead at 245 ppm which is quite low compared to other lead concentrations encountered at this training area. No action is required at this site.

3.4 Urban Assault Range

This range is located northeast of Ortona and is used to simulate detonation impacts on buildings and also used for small arms practice. Usually, military personnel place C-4 blocks on the side of the road that explode close to structures that imitate houses. (Figs. 7-8). There was also a railway track used to move targets for small arms but this was not sampled in Phase I.

In Phase II, no metal analyses were done on any sample since no problems were identified at that site. Composite samples were collected at six locations according to Figure 9, including soil samples in and around the wooden structures (Fig. 10). No energetic materials were detected in any of the samples. This site is considered clean of energetic residues.

3.5 Cassino Range

This range was quite new and was used to practice 40 mm grenade launches and small arms target shooting (Figs. 11-14). The 40 mm are supposed to be of the self-destruct type. No sampling was done in the 40 mm impact area during Phase I. No energetic materials were found during Phase I. It was concluded that this site was not contaminated by explosives and that the impact area for 40 mm should be screened for explosives during the next sampling in August 2008. This was done in Phase II where we composite-sampled the impact area of the 40 mm and also the target areas for the small arms shooting. No energetic materials were detected in any sample. Only Sb, Tl and Cd exceeded the BGL concentrations at very low levels. This site is not considered contaminated.

3.6 Caen Range

As already mentioned, Caen is similar to Cambrai and Dieppe which served as firing positions for many types of weapons such as: 105 mm Leopard tank, LAV Cougar 76 mm, Grizzly for 25 mm medium calibre, 105 mm Howitzer artillery gun, mortars, etc. It has a large, 90 m wide concrete pad. The Caen site is located on the right side of the observation tower (Fig. 3).

During Phase I, for energetic materials in Caen, the concrete pad was measured and its 90 m width was divided into six sections of 15 m. Composite samples were built in front of the concrete pad in front of the specific 15 m wide areas with a depth of 10 m and were named M-07-Caen-1, 2, 3,... and 6 from left to right. It was found that nitroglycerine was detected in all samples at concentrations varying from 3.32 to 67.24 ppm. There was no specific pattern of deposition along the pad indicating that its entire width was used for the firings. 2,4-DNT was also observed at concentrations varying from 6.84 to 47.96 ppm. For the first time, some 2,6-DNT was detected in some of these samples at concentrations varying from 0.76 to 1.70 ppm. It was concluded that all the nitroglycerine and DNT concentrations are very low and of no concern at this moment and do not represent a problem. No action was required on this site.

During Phase II, we wanted to re-evaluate this site to verify if the concentrations increased over time and to see if they were reproducible. A different strategy was used and samples were collected at 10, 20 and 30 meters in front of the areas between 0-15 meters and 30-45 meters of the concrete pad. These samples were named 1 to 6 according to Figure 15. Furthermore, burning spots were observed in front of the pad and these areas were composited to build a sample named M08-CAEN-7 (Fig. 16).

If one examines Table 5, it can be seen that nitroglycerine and 2,4-DNT were detected in all samples at concentrations similar to the ones observed in Phase I, the highest concentrations of nitroglycerine and 2,4-DNT being respectively 166 and 104 ppm. This time, the area in front of 0-15 m seems more contaminated than the area in front of 30-45 meters. In front of the area at 0-15 m, the concentrations are going down with distances (10 to 30 meters) from 166 to 32 ppm for nitroglycerine and from 104 to 5 ppm for 2,4-DNT. 2,6-DNT was also observed in some samples. The area in front of 30-45 meters seems to keep the same concentrations with distances having concentrations of 36 ppm for nitroglycerine. 2,4-DNT concentrations decreased more dramatically with distances in both areas. In general, it can be said that the concentrations are similar to the ones observed during Phase I, so the concentrations of propellant residues did not increase much after one year. The reproducibility of the results indicates that the sampling method, the sample treatment and the analytical chemistry are adequate. It can still be concluded that all the nitroglycerine and DNT concentrations are very low and of no concern at this moment and do not represent a problem. No action was required on this site.

3.7 Position 409

During our first visit in April 2007, we stopped at a firing position named position 408 where 105 mm artillery guns and 81 mm mortars were fired. Just besides this position on the road, there was another firing location named Position 409. This position was sampled for energetic materials. Composite soil samples were collected to evaluate this position. Two composite samples were

built and named M-08-S-P409-MOAC-1 and 2. No energetic materials were found at this location.

3.8 Gravel Pit

The Gravel Pit is the location where all the materials, such as rocks, sand and gravel stockpiles needed for the activities of the base are stored. This site is also used for pyrotechnics disposal by open burning. Pyrotechnics contain metals, perchlorate and energetic materials that may contaminate the site during the combustion. Samples were collected at that site to evaluate if this burning had an impact on the site and three composite samples were collected for energetic materials, metals and perchlorate. Unfortunately, the perchlorate analysis was not performed and this sample was analyzed only for metal, making two samples for metals in this site. Being ionic, the perchlorates are highly soluble and it would be almost impossible to catch them especially if burning was done a long time ago and if it rained on the site prior to the sampling. This analysis was requested mostly by curiosity and there are no drawback for not having done this analysis.

No energetic materials were detected at that site. Both samples for metal analyses revealed the same problematic metals at similar concentrations proving again that multi increment sampling is the best method for sampling. Cr, Cu, Pb, As, Tl, Zn and Cd were observed at concentrations higher than the ISQGL, the highest proportion being for arsenic at more than 10 times the ISQGL. Sb, Ag, Ba and B were also observed at concentrations higher than the BGL or the ASQGL. Recommendations will be made in the next section to deal with this problem.

3.9 Recommendations

In general, levels of metals in soils are close to the BGL in the majority of samples taken except at the grenade range, around the target tanks in Cambrai, in the Gravel Pit and in the small arms ranges. Furthermore, concentrations were typically far below the ASQG or the ISQG. As mentioned in the Phase I report, this means that most of the training area is in good condition and can be used for training. Some metals that were systematically present at high concentrations, such as lead, chromium, copper, antimony, arsenic, zinc, and cadmium can be related to firing activities. Selenium was found around tank targets in Cambrai at high concentrations but this situation was not confirmed during Phase II. This could be explained by sample pre-treatment that may have differed from commercial laboratories. The fact that metal concentrations were generally low is the direct result of good management practices performed by range control and the less intense use of this training area.

The energetic materials analysis revealed that there are no major impacts related to the activities at this training area and this was confirmed by Phase II results. Some hot spots were found but their concentrations are lower than what is usually found in other similar training areas.

No action is required in most ranges of the training area except to continue to clean up and manage the sites as it is currently done. However, metal concentrations in the small arms ranges should be monitored periodically. Although most of them did not exceed the ISQG criteria, many of the results are higher than the ASQG. Since these sites will not be used for agriculture, but will continue to be used for target practice, respect of the ASQG is not mandatory. Groundwater metal

concentrations will have to be monitored to evaluate if the potential contamination is migrating towards the groundwater table.

As for the areas that present higher concentrations of heavy metals, an intervention is to be envisioned. Different approaches can be taken when metal concentrations are higher than the ISQGL. Since CCME criteria values are risk based, when speaking of metal concentrations that are higher than the ISQGL criteria, this means that there are risks for human health or other receptors. Usually, soil is excavated and managed in a secure landfill. Effectiveness is assured when the activities stop definitively. Considering that the training must and will continue, the contamination will come back after the clean-up and the accumulation will continue. Considering this particular situation, another approach could be used. It implies minimizing exposure of potential receptors to the contamination. One must know that exposure management is a solution while the site is still being used, but actions should be taken to keep concentrations as low as possible. Removing debris from time to time is a good example of what can be done to minimize the concentrations. In the end, excavation of contaminated soil will eventually be required to respect the ISQG.

The easiest way of minimizing the exposition of receptors is also forbidding them to enter the zone. In this sense, fencing and controlling access are normally a good option but in the present case, it does not appear really feasible because of the size of the site and also because of the type of activities conducted in our ranges. The small arms, the target positions and the grenade ranges are open areas where the activities are taking place. In ranges such as the grenade or small arms, fencing could be done but for the target locations, it does not appear feasible. In some instances, excavation will be the only action and removing the contaminated soils and shipping them to a secure landfill will have to be done even if this option is expensive.

For the small arms ranges, efforts are currently being made to propose solutions, but in the meantime, management of the sand butts should be done. At Meaford small arms training areas, the concentrations of lead are quite low compared to other Canadian bases and it is recommended to have a surveillance programme for both the sand butt metal concentrations and the groundwater quality initiated to monitor the metal concentrations. Metal concentrations monitoring in groundwater is especially important since it will tell if metals are moving out of the ranges.

For the grenade range, it is foreseen that efforts will eventually be made to solve the issues related to grenade range activities, but in the meantime, fencing the area would not cost too much since it is a small range and this should limit significantly human and large mammal exposure. The other option would be to excavate the contaminated area until lower concentrations of zinc are measured and send these contaminated soils to a secure landfill. It is understood that the activity will continue, but if these actions are taken, it will sustain the activity for another time period.

The Gravel Pit should no longer be used to burn pyrotechnics since this activity leads inevitably to metal contamination as the burning of propellant bags leads to DNT contamination. The destruction of pyrotechnics should be done on a burning table similar to the one DRDC Valcartier is developing for propellant bags. The burning area of the Gravel Pit is quite small and the soil should be excavated and sent to a secure landfill as already mentioned for the other contaminated areas. Finally, it is highly recommended to clean the tank areas in Cambrai since they represent a real danger to human health and other receptor health, having concentrations of 1000 times the

ISQGL. Normally for all these mentioned areas, the contamination is located at the surface and the excavation should not go deeper than 8 inches and soil concentrations must be evaluated after the excavation to see if the concentrations were removed.

When groundwater results of INRS Phase II will be available, a surveillance programme for groundwater monitoring will have to be initiated to monitor the groundwater quality. Such a surveillance programme will be discussed and presented to the training area management as soon as all the data are available.

4 Conclusion

In September 2007, DRDC Valcartier and INRS conducted for Director Land Environment (DLE) the first phase to characterize the soil, surface water and groundwater for metals and energetic materials at Land Force Central Area Training Centre (LFCATC) Meaford, Ontario. The Institut national de la recherche scientifique (INRS) was responsible for sampling the surface water and groundwater for metals and explosives and produced a separate report describing their results. In our study, most of the ranges of the LFCA TC Meaford were sampled during the September 2007 campaign. A total of 17 ranges were sampled to evaluate the explosives and/or metals contamination. More precisely, at the small arms ranges, skeet range, artillery firing positions, anti-tank, grenade and other ranges, 135 soil samples were collected including 79 for energetic materials, 56 for metals and seven for polycyclic aromatic hydrocarbons (PAHs) analyses. Water samples (35) were collected by INRS, analysed by DRDC Valcartier and revealed no energetic materials. Twenty background samples were taken for the metals evaluation and served as comparison. Metals were analysed in Apeldorn grenade range, Cambrai, Ortona, Urban Assault, Paardeburg anti-tank, and in all the small arms ranges Gully, Alpha, Gravenstafel Ridge and Skeet ranges. Metal analyses were done using Inductively Coupled Plasma /Mass Spectrometry (ICP/MS) and explosives concentrations were determined using the High Pressure Liquid Chromatography (HPLC) Method EPA 8330b.

In August 2008, DRDC Valcartier conducted Phase II of this study to complete its understanding of the issues identified during Phase I. Nine ranges were sampled for the explosives and/or metals contamination. More precisely, the Apeldorn grenade range was re-visited to confirm metal concentrations observed during Phase I, the Caen range was re-sampled to confirm propellant residues concentrations while the Cambrai target positions were re-sampled to examine the high selenium concentrations observed during Phase I. In Cassino, small arms target positions were evaluated for metal concentrations while the 40 mm impact area was evaluated for energetic residues. The urban assault portion of Ortona range was sampled for energetics while Normandy, Position 409 and the Gravel Pit were sampled for energetics and metals. Forty-one soil samples were collected and analysed, including 21 for energetic materials, 20 for metals and one for perchlorate analyses. The 20 soil background samples taken for the metals evaluation during Phase I served again for comparison purposes during Phase II. Metal analyses were done using Inductively Coupled Plasma /Mass Spectrometry (ICP/MS) and explosives concentrations were determined using the High Pressure Liquid Chromatography (HPLC) Method EPA 8330b.

Many different sampling strategies were used to collect samples across the ranges and were explained in detail. In general, results from Phase I showed that the concentrations of metals in soils in most of the ranges were quite low. Most of the time, the metals detected at concentrations higher than the BGL were far below the ASQG or the ISQGL except for some metals such as lead, chromium, copper, antimony, arsenic, zinc, and cadmium, which were present at higher concentrations. These metals can be related to firing activities. Selenium was found at high concentrations around tank targets at Cambrai and this was investigated further. The fact that metals concentrations were generally low in the ranges is the direct result of good management of the sites performed by range control and the low use of this training area compared to other highly used Canadian Forces Bases.

The energetic materials analyses revealed that there are no major impacts related to the activities at this training area. Some hot spots were found but their concentrations were lower than what is usually found in other similar training areas. Good examples of this are the targets in the Paardeburg anti-tank range that are contaminated by HMX at concentrations of 1,300 ppm while other anti-tank ranges at other bases showed HMX concentrations up to 7,000 ppm. The same situation is encountered with small arms ranges where maximum lead concentrations were found in Alpha at 6,000 ppm while in other typical small arms ranges, lead concentrations reached 70,000 ppm.

During Phase II, the results confirmed that the firing positions of Caen are contaminated by nitroglycerine and 2,4-DNT. Surprisingly, the tank positions in Cambrai still highly contaminated by metals did not show selenium at extreme concentrations as in Phase I. Except for the firing positions in Caen, no energetic materials were detected in any of the samples collected. The Apeldorn grenade range still showed high zinc concentrations as for the Gravel Pit that showed many metal concentrations higher than the Canadian Council of Ministers of Environment (CCME) Industrial Soil Quality Guideline threshold criteria.

In general, the soils are of acceptable quality. No action is required on most of the sites except to continue to clean and manage the sites as is currently done. Metal concentrations in the small arms ranges are to be monitored from time to time. Although, most of them did not exceed the ISQG criteria, many of the results are higher than the ASQG. As already mentioned, no action is required, since the site will not be used for agriculture, but will continue to be used for target practice. The most important results will come from the hydrogeological study since they will confirm if there is a contamination and if it is moving out of the ranges.

Following Phase II results, recommendations were made to excavate soils contaminated by metals at the grenade range, especially at the target tank position in Cambrai where concentrations are 1000 times higher than the ISQGL. It was also recommended that the Gravel Pit be cleaned by excavation and that the burning of pyrotechnics be stopped and allowed to proceed only on a burning table where the ashes containing the metals will be dealt with. A burning table under development at DRDC Valcartier should be used for this activity. For small arms ranges, the concentrations being quite low, it was recommended to install a surveillance programme to monitor the concentrations of metals in soils and in groundwater.

In conclusion, this study demonstrated that the ranges have some accumulation of metals due to firing activities in some parts of the ranges, but the extent of contamination is quite low in general. The Apeldorn grenade range, the tanks in Cambrai and the Gravel Pit need actions while most of the ranges need no action or surveillance programmes. Contamination by explosives is also minimal except around targets in the Paardeburg anti-tank range and at firing positions in Cambrai, Caen and Dieppe. Nitroglycerine was observed at 4,000 ppm in the firing positions of the Paardeburg anti-tank range. Compared to other bases where concentrations as high as 20,000 ppm were observed, it can be said that the Meaford firing positions are quite clean.

5 Figures



Figure 1: The Bunker in Apeldorn Grenade Range.

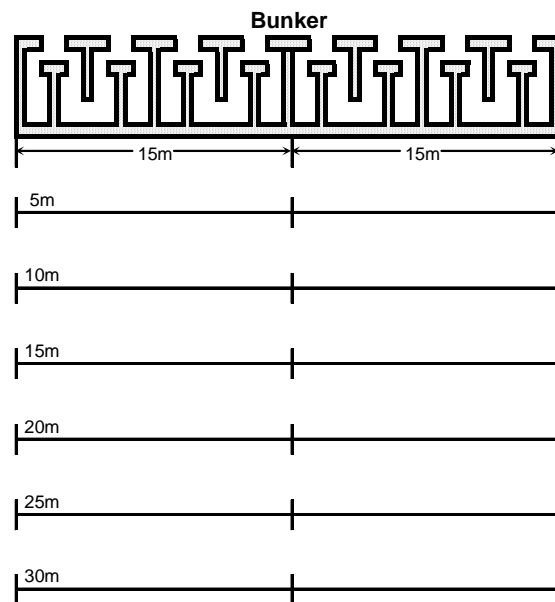


Figure 2: Sampling Strategy in Apeldorn Grenade Range.

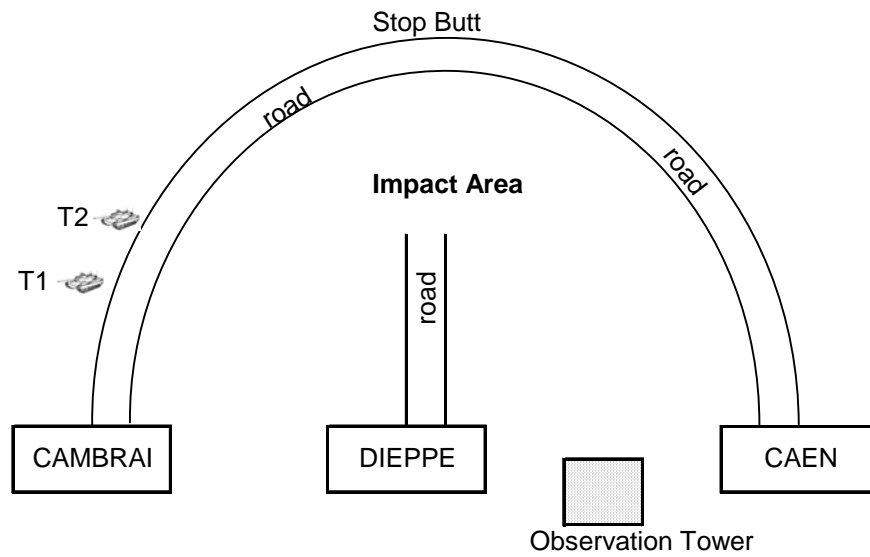


Figure 3: Locations of Ranges around the Observation Tower.

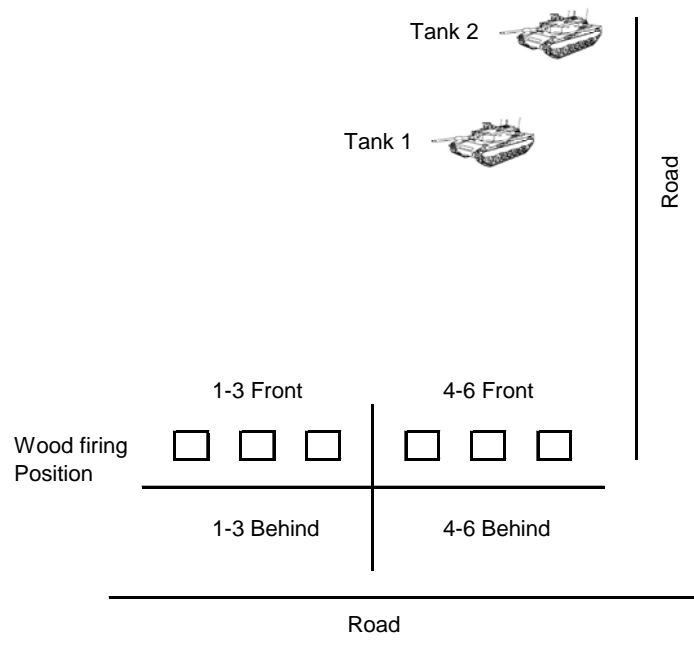


Figure 4: Sampling around Tanks in Cambrai Range.

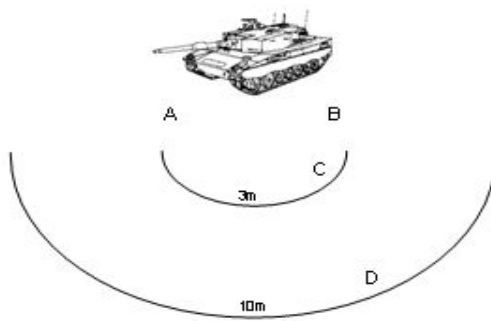


Figure 5: Sampling Strategy around Tanks in Cambrai.



Figure 6: Target Berm in Normandy Range.

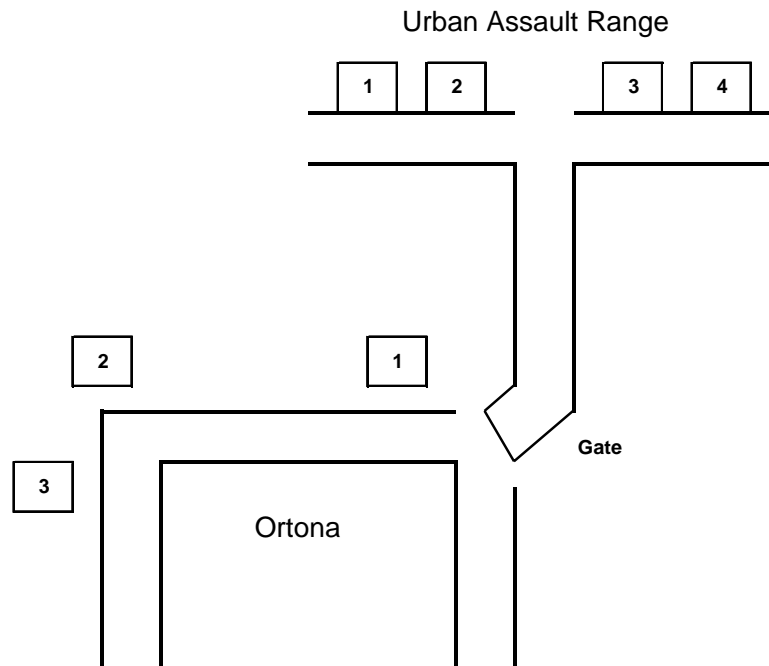


Figure 7: Sampling Strategy in Ortona and Urban Assault Ranges



Figure 8: Sampling a House in Ortona Range.

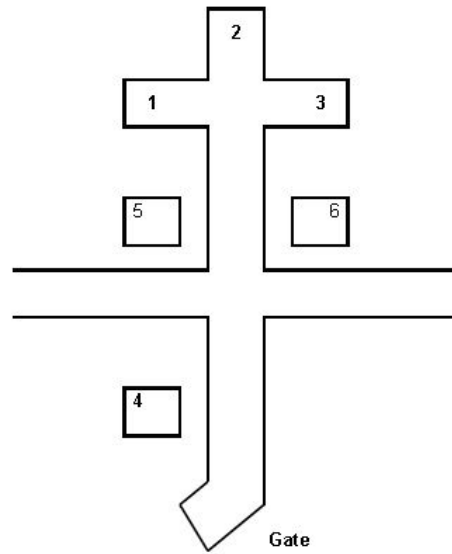


Figure 9: Sampling Strategy in Urban Assault Range.



Figure 10: Structures Mimicking Houses in Urban Assault Range.

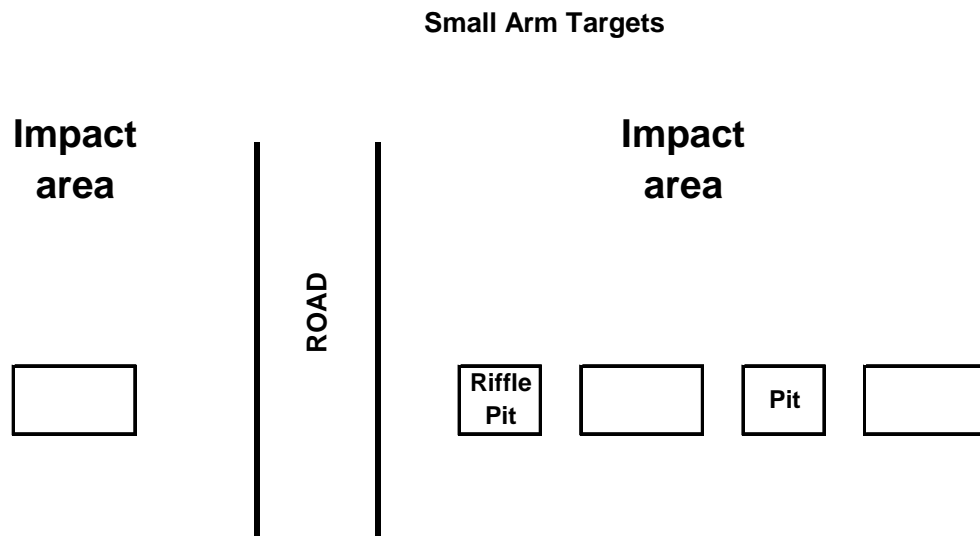


Figure 11: Sampling Strategy in Cassino Range.



Figure 12: Firing Positions in Cassino Range.



Figure 13: Impact Area of 40 mm in Cassino Range.



Figure 14: Target Area for Small Arms in Cassino Range.

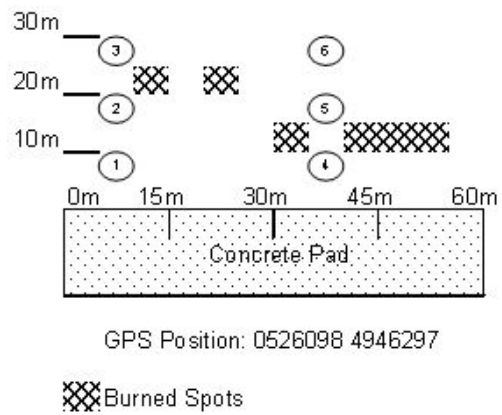


Figure 15: Sampling Strategy in Caen Range.



Figure 16: Burning Spots in Front of the Concrete Pad in Caen Range.

6 Tables

Table 1: GPS LOCATIONS OF SAMPLING.

Sampling Locations or Sample ID	Sampling Point	
	X or Northern	Y or Western
BACKGROUND SAMPLES		
M-07-BG-1	0525601	4945850
M-07-BG-2	0527214	4946032
M-07-BG-3 and M-07-BG-4 (same locations)	0528126	4946463
M-07-BG-5	0528753	4946398
M-07-BG-6	0528783	4947485
M-07-BG-7	0528723	4947929
M-07-BG-8	0528630	4948486
M-07-BG-9	0528524	4949159
M-07-BG-10	0528437	4949676
M-07-BG-11	0528239	4950822
M-07-BG-12	0527515	4951098
M-07-BG-13	0526238	4950895
M-07-BG-14	0527073	4952099
M-07-BG-15	0524781	4951520
M-07-BG-16	0521314	4949873
M-07-BG-17	0520211	4948596
M-07-BG-18	0520564	4946535
M-07-BG-19	0521689	4945465
M-07-BG-20	0526350	4945902
NORMANDY		
M08-S-NORM-MP	0525010	4946166
M08-S-NORM-left of stop butt	0524715	4946941
M08-S-NORM-right of stop butt	0524745	4946965
CASSINO		
M08-CAS-T1	0523607	4946833

Sampling Locations or Sample ID	Sampling Point	
	X or Northern	Y or Western
M08-CAS-T2	0523613	4946815
M08-CAS-MOAC 1 and 2	0523573	4946826
POSITION 409		
M08-S-P409-MOAC 1 and 2	0523481	4946170
CAMBRAI		
Tank 1 for M08-CAM-T1 A,B,C	0525827	4946304
Tank 2 for M08-CAM-T2 A-D	0525764	4946424
CAEN		
Concrete pad	0526094	4946297
M08-CAEN-7 6 burned areas were composited	0526101	4946301
	0526104	4946301
	0526114	4946303
	0526117	4946304
	0526127	4946304
	0526130	4946305
URBAN ASSAULT RANGE NORTHEAST OF ORTONA		
M08-S-UA-MOAC-1	0522453	4946800
M08-S-UA-MOAC-2	0522464	4946810
M08-S-UA-MOAC-3	0522472	4946793
M08-S-UA-MOAC-4	0522258	4946511
M08-S-UA-MOAC-cabane5	0522443	4946727
M08-S-UA-MOAC-cabane6	0522475	4946723
GRAVEL PIT		
M08-S-GP-MOAC 1-3	0528682	4951331

Table 2: METALS CONCENTRATIONS IN SOILS (Sb to Cd)

	Sb	As	Ba	Be	B	Cd
Sample	ppm (mg/kg)					
BACKGROUND SAMPLES						
M-07-BG-1	0.4	3	24	0.4	0.21	0.2
M-07-BG-2	0.4	11	94	0.8	0.20	0.5
M-07-BG-3	0.4	3	36	0.7	0.42	0.2
M-07-BG-4	0.4	3	38	0.6	0.41	0.2
M-07-BG-5	0.4	4	25	0.4	0.19	0.2
M-07-BG-6	0.4	6	69	0.7	0.47	0.4
M-07-BG-7	0.4	4	27	0.4	0.23	0.2
M-07-BG-8	0.4	4	31	0.4	0.53	0.2
M-07-BG-9	0.4	4	43	0.6	0.92	0.2
M-07-BG-10	0.4	4	26	0.4	0.66	0.2
M-07-BG-11	0.4	9	62	0.4	0.51	0.3
M-07-BG-12	0.4	5	48	0.5	0.92	0.3
M-07-BG-13	0.4	4	32	0.4	0.20	0.2
M-07-BG-14	0.4	5	39	0.4	0.19	0.2
M-07-BG-15	0.4	4	34	0.4	0.30	0.2
M-07-BG-16	0.4	11	42	0.8	0.22	0.2
M-07-BG-17	0.4	4	40	0.6	0.35	0.2
M-07-BG-18	0.4	4	40	0.6	0.49	0.2
M-07-BG-19	0.4	4	27	0.4	0.62	0.2
M-07-BG-20	0.4	2	16	0.7	0.03	0.2
Average	0.4	5	40	0.5	0.40	0.2
Standard deviation	0.0	3	18	0.1	0.24	0.1
(2 x St Dev))	0.0	5	36	0.3	0.48	0.2
Sum (Ave+(2xStDev)	0.4	10	76	0.8	0.89	0.4
CCME ASQG (a)	20	12	750	4	2	1.4
CCME ISQG (b)	40	12	2000	8		2.2
APELDORN GRENADE RANGE						
M08-AGR-0-5 M	0.5	3	61	0.3	0.05	0.5
M08-AGR-5-10 M	0.5	2	89	0.3	0.05	0.5

	Sb	As	Ba	Be	B	Cd
Sample	ppm (mg/kg)					
M08-AGR-10-15 M	0.5	2	84	0.3	0.05	0.5
M08-AGR-15-20 M	38.0	2	83	0.3	0.05	0.5
M08-AGR-20-25 M	0.5	2	88	0.3	0.05	0.5
M08-AGR-25-30 M	27.0	2	39	0.3	0.05	0.5
CAMBRAI						
M08-CAM-T1A	8480	60	156	0.5	0.50	4.0
M08-CAM-T1B	9570	60	146	0.3	0.40	3.0
M08-CAM-T1C	1470	15	129	0.3	0.40	0.5
M08-CAM-T2A	18800	130	278	0.3	0.40	18.0
M08-CAM-T2B	21400	160	309	0.3	0.40	9.0
M08-CAM-T2C	2140	23	104	0.7	0.30	3.0
M08-CAM-T2D	751	11	121	0.7	0.10	1.0
M08-CAM-T2D (DUP)	683	12	95	0.8	0.20	0.5
NORMANDY						
M08-NORM-LEFT	4.0	3	32	0.6	0.50	0.5
M08-NORM-RIGHT	2.0	3	36	0.6	0.30	0.5
CASSINO						
M08-CAS-T1	1.0	5	29	0.3	0.10	0.5
M08-CAS-T2	0.5	4	27	0.3	0.20	0.5
GRAVEL PIT						
M08-GP-MOAC-2	13.0	163	682	0.3	2.00	5.0
M08-GP-MOAC-3	13.0	113	806	0.3	2.00	14.0

a: ASQG Agricultural Soil Quality Guideline

b: ISQG Industrial Soil Quality Guideline

Note: half values of the detection limits are used when metals are not detected

Values higher than the background mean + 2 x the standard deviation are highlighted in blue

Values higher than the CCME ASQG are highlighted in green

Values higher than the CCME ISQG are highlighted in red

Table 3: METALS CONCENTRATIONS IN SOILS (Cr to Mo)

	Cr	Co	Cu	Pb	Hg	Mo
Sample	ppm (mg/kg)					
BACKGROUND SAMPLES						
M-07-BG-1	13	9	15	10	0.05	1
M-07-BG-2	19	10	40	19	0.07	1
M-07-BG-3	15	12	42	10	0.05	1
M-07-BG-4	15	12	40	10	0.05	1
M-07-BG-5	6	5	25	7	0.05	1
M-07-BG-6	21	14	30	15	0.05	1
M-07-BG-7	6	5	29	7	0.05	1
M-07-BG-8	7	5	25	7	0.05	1
M-07-BG-9	16	8	23	17	0.05	1
M-07-BG-10	12	10	24	10	0.05	1
M-07-BG-11	7	6	19	21	0.05	1
M-07-BG-12	12	9	39	18	0.05	1
M-07-BG-13	6	5	29	7	0.05	1
M-07-BG-14	7	5	37	8	0.05	1
M-07-BG-15	8	6	34	52	0.05	1
M-07-BG-16	16	18	36	12	0.05	1
M-07-BG-17	16	10	23	11	0.05	1
M-07-BG-18	16	10	31	11	0.05	1
M-07-BG-19	8	6	18	9	0.05	1
M-07-BG-20	17	11	13	4	0.05	1
Average	12	9	29	13	0.05	1
Standard deviation	5	4	9	10	0.00	0
(2 x St Dev))	10	7	17	20	0.01	0
Sum (Ave+(2xStDev)	22	16	46	34	0.06	1
CCME ASQG (a)	64	40	63	70	7	5
CCME ISQG (b)	87	300	91	600	50	40
APELDORN GRENADE RANGE						
M08-AGR-0-5 M	21	3	32	38	0.03	1
M08-AGR-5-10 M	28	3	35	55	0.03	1
M08-AGR-10-15 M	23	3	54	48	0.03	1
M08-AGR-15-20 M	23	3	52	675	0.03	1

	Cr	Co	Cu	Pb	Hg	Mo
Sample	ppm (mg/kg)					
M08-AGR-20-25 M	27	3	31	42	0.03	1
M08-AGR-25-30 M	13	3	28	440	0.03	1
CAMBRAI						
M08-CAM-T1A	51	280	12600	147000	0.11	21
M08-CAM-T1B	49	378	13800	146000	0.13	20
M08-CAM-T1C	13	35	3970	32300	0.03	4
M08-CAM-T2A	60	325	21000	318000	0.28	25
M08-CAM-T2B	60	488	23400	402000	0.24	35
M08-CAM-T2C	33	66	5750	33300	0.07	7
M08-CAM-T2D	26	47	2630	18000	0.03	3
M08-CAM-T2D (DUP)	26	35	4580	16900	0.05	3
NORMANDY						
M08-NORM-LEFT	18	10	27	62	0.03	1
M08-NORM-RIGHT	18	9	30	245	0.03	1
CASSINO						
M08-CAS-T1	8	6	37	22	0.03	1
M08-CAS-T2	7	5	34	14	0.03	1
GRAVEL PIT						
M08-GP-MOAC-2	90	8	442	906	0.03	1
M08-GP-MOAC-3	76	8	539	810	0.03	1

a: ASQG Agricultural Soil Quality Guideline

b: ISQG Industrial Soil Quality Guideline

Note: half values of the detection limits are used when metals are not detected

Values higher than the background mean + 2 x the standard deviation are highlighted in blue

Values higher than the CCME ASQG are highlighted in green

Values higher than the CCME ISQG are highlighted in red

Table 4: METALS CONCENTRATIONS IN SOILS (Ni to Zn)

	Ni	Se	Ag	Tl	V	Zn
Sample	ppm (mg/kg)					
BACKGROUND SAMPLES						
M-07-BG-1	20	2	0.2	0.1	15	47
M-07-BG-2	16	2	0.2	0.2	23	53
M-07-BG-3	22	2	0.2	0.1	19	47
M-07-BG-4	22	2	0.2	0.1	17	49
M-07-BG-5	9	2	0.2	0.1	9	24
M-07-BG-6	28	2	0.2	0.1	23	86
M-07-BG-7	9	2	0.2	0.1	9	25
M-07-BG-8	10	2	0.2	0.1	9	22
M-07-BG-9	22	2	0.2	0.1	19	49
M-07-BG-10	20	2	0.2	0.1	14	55
M-07-BG-11	10	2	0.2	0.1	13	43
M-07-BG-12	18	2	0.2	0.1	15	57
M-07-BG-13	10	2	0.2	0.1	9	27
M-07-BG-14	12	2	0.2	0.1	11	31
M-07-BG-15	13	2	0.2	0.1	12	39
M-07-BG-16	26	2	0.2	0.1	20	50
M-07-BG-17	19	2	0.2	0.1	20	50
M-07-BG-18	19	2	0.2	0.1	20	53
M-07-BG-19	11	2	0.2	0.1	11	33
M-07-BG-20	27	2	0.2	0.1	15	48
Average	17	2	0.2	0.1	15	44
Standard deviation	6	0	0.0	0.0	5	15
(2 x St Dev))	13	0	0.0	0.0	9	30
Sum (Ave+(2xStDev)	30	2	0.2	0.1	25	74
CCME ASQG (a)	50	1	20	1	130	200
CCME ISQG (b)	50	3.9	40	1	130	360
APELDORN GRENADE RANGE						
M08-AGR-0-5 M	29	1	0.1	0.5	6	1190
M08-AGR-5-10 M	44	1	0.1	0.5	6	1710
M08-AGR-10-15 M	36	1	0.1	0.5	6	1720
M08-AGR-15-20 M	34	1	0.1	0.5	7	1590

	Ni	Se	Ag	Tl	V	Zn
Sample	ppm (mg/kg)					
M08-AGR-20-25 M	36	1	0.1	0.5	8	1560
M08-AGR-25-30 M	16	1	0.1	0.5	9	605
CAMBRAI						
M08-CAM-T1A	60	5	10.9	3.0	19	1740
M08-CAM-T1B	60	5	11.9	3.0	17	1800
M08-CAM-T1C	15	1	1.9	0.5	22	459
M08-CAM-T2A	94	5	52.0	5.0	14	2330
M08-CAM-T2B	88	5	30.5	6.0	13	2530
M08-CAM-T2C	35	1	3.5	1.0	25	617
M08-CAM-T2D	29	1	1.4	0.5	30	323
M08-CAM-T2D (DUP)	25	1	1.4	0.5	29	447
NORMANDY						
M08-NORM-LEFT	19	1	0.1	0.5	23	53
M08-NORM-RIGHT	17	1	0.1	0.5	24	56
CASSINO						
M08-CAS-T1	10	1	0.1	0.5	9	28
M08-CAS-T2	9	1	0.1	0.5	8	24
GRAVEL PIT						
M08-GP-MOAC-2	19	1	0.3	2.0	12	1540
M08-GP-MOAC-3	18	1	0.3	2.0	12	1420

a: ASQG Agricultural Soil Quality Guideline

b: ISQG Industrial Soil Quality Guideline

Note: half values of the detection limits are used when metals are not detected

Values higher than the background mean + 2 x the standard deviation are highlighted in blue

Values higher than the CCME ASQG are highlighted in green

Values higher than the CCME ISQG are highlighted in red

Table 5: PROPELLANT RESIDUES IN SOILS BY HPLC IN PPM (NG and DNTs)

Sample	Lab No	NG	2,4-DNT	2,6-DNT
CAEN				
M-08-CAEN-1	S-MEAF08-1a	165.92	103.88	3.12
	1b	145.48	91.26	2.64
	mean	155.70	97.57	2.88
M-08-CAEN-2	S-MEAF08-2a	64.20	10.44	n.d.
	2b	49.28	8.82	n.d.
	mean	56.74	9.63	n.d.
M-08-CAEN-3	S-MEAF08-3a	32.56	5.46	n.d.
	3b	31.42	5.26	n.d.
	mean	31.99	5.36	n.d.
M-08-CAEN-4	S-MEAF08-4a	36.36	18.36	n.d.
	4b	29.72	14.40	n.d.
	mean	33.04	16.38	n.d.
M-08-CAEN-5	S-MEAF08-5a	38.26	4.08	n.d.
	5b	37.62	3.90	n.d.
	mean	37.94	3.99	n.d.
M-08-CAEN-6	S-MEAF08-6a	31.06	3.20	n.d.
	6b	30.18	3.06	n.d.
	mean	30.62	3.13	n.d.
M-08-CAEN-7	S-MEAF08-7a	134.24	84.72	1.90
	7b	120.16	75.54	1.70
	mean	127.20	80.13	1.80
URBAN ASSAULT ON ORTONA				
M08-S-UA-Moac-1	S-MEAF08-8az	n.d.	n.d.	n.d.
	8bz	n.d.	n.d.	n.d.
M08-S-UA-Moac-2	S-MEAF08-9az	n.d.	n.d.	n.d.
	9bz	n.d.	n.d.	n.d.
M08-S-UA-Moac-3	S-MEAF08-10az	n.d.	n.d.	n.d.
	10bz	n.d.	n.d.	n.d.
M08-S-UA-Moac-4	S-MEAF08-11az	n.d.	n.d.	n.d.
	11bz	n.d.	n.d.	n.d.

Sample	Lab No	NG	2,4-DNT	2,6-DNT
M08-S-UA-Cabane 5	S-MEAF08-12az	n.d.	n.d.	n.d.
	12bz	n.d.	n.d.	n.d.
M08-S-UA-Cabane 6	S-MEAF08-13az	n.d.	n.d.	n.d.
	13bz	n.d.	n.d.	n.d.
POSITION 409				
M08-S-P409-Moac-1	S-MEAF08-14az	n.d.	n.d.	n.d.
	14bz	n.d.	n.d.	n.d.
M08-S-P409-Moac-2	S-MEAF08-15az	n.d.	n.d.	n.d.
	15bz	n.d.	n.d.	n.d.
NORMANDY				
M08-NORM-RIGHT	S-MEAF08-16az	n.d.	n.d.	n.d.
	16bz	n.d.	n.d.	n.d.
M08-NORM-LEFT	S-MEAF08-17az	n.d.	n.d.	n.d.
	17bz	n.d.	n.d.	n.d.
M08-NORM-MP	S-MEAF08-18az	n.d.	n.d.	n.d.
	18bz	n.d.	n.d.	n.d.
CASSINO				
M08-S-CAS-Moac-1	S-MEAF08-19az	n.d.	n.d.	n.d.
	19bz	n.d.	n.d.	n.d.
M08-S-CAS-Moac-2	S-MEAF08-20az	n.d.	n.d.	n.d.
	20bz	n.d.	n.d.	n.d.
GRAVEL PIT				
M08-S-GP-Moac-1	S-MEAF08-21az	n.d.	n.d.	n.d.
	21bz	n.d.	n.d.	n.d.

n.d.: not detected

Table 6: EXPLOSIVES IN SOILS BY HPLC IN PPM (TNT, RDX AND HMX)

Sample	Lab No	HMX	RDX	TNT
CAEN				
M-08-CAEN-1	S-MEAF08-1a	n.d.	n.d.	n.d.
	1b	n.d.	n.d.	n.d.
	mean	n.d.	n.d.	n.d.
M-08-CAEN-2	S-MEAF08-2a	n.d.	n.d.	n.d.
	2b	n.d.	n.d.	n.d.
	mean	n.d.	n.d.	n.d.
M-08-CAEN-3	S-MEAF08-3a	n.d.	n.d.	n.d.
	3b	n.d.	n.d.	n.d.
	mean	n.d.	n.d.	n.d.
M-08-CAEN-4	S-MEAF08-4a	n.d.	n.d.	n.d.
	4b	n.d.	n.d.	n.d.
	mean	n.d.	n.d.	n.d.
M-08-CAEN-5	S-MEAF08-5a	n.d.	n.d.	n.d.
	5b	n.d.	n.d.	n.d.
	mean	n.d.	n.d.	n.d.
M-08-CAEN-6	S-MEAF08-6a	n.d.	n.d.	n.d.
	6b	n.d.	n.d.	n.d.
	mean	n.d.	n.d.	n.d.
M-08-CAEN-7	S-MEAF08-7a	n.d.	n.d.	n.d.
	7b	n.d.	n.d.	n.d.
	mean	n.d.	n.d.	n.d.
URBAN ASSAULT ON ORTONA				
M08-S-UA-Moac-1	S-MEAF08-8az	n.d.	n.d.	n.d.
	8bz	n.d.	n.d.	n.d.
M08-S-UA-Moac-2	S-MEAF08-9az	n.d.	n.d.	n.d.
	9bz	n.d.	n.d.	n.d.
M08-S-UA-Moac-3	S-MEAF08-10az	n.d.	n.d.	n.d.
	10bz	n.d.	n.d.	n.d.
M08-S-UA-Moac-4	S-MEAF08-11az	n.d.	n.d.	n.d.
	11bz	n.d.	n.d.	n.d.

Sample	Lab No	HMX	RDX	TNT
M08-S-UA-Cabane 5	S-MEAF08-12az	n.d.	n.d.	n.d.
	12bz	n.d.	n.d.	n.d.
M08-S-UA-Cabane 6	S-MEAF08-13az	n.d.	n.d.	n.d.
	13bz	n.d.	n.d.	n.d.
POSITION 409				
M08-S-P409-Moac-1	S-MEAF08-14az	n.d.	n.d.	n.d.
	14bz	n.d.	n.d.	n.d.
M08-S-P409-Moac-2	S-MEAF08-15az	n.d.	n.d.	n.d.
	15bz	n.d.	n.d.	n.d.
NORMANDY				
M08-NORM-RIGHT	S-MEAF08-16az	n.d.	n.d.	n.d.
	16bz	n.d.	n.d.	n.d.
M08-NORM-LEFT	S-MEAF08-17az	n.d.	n.d.	n.d.
	17bz	n.d.	n.d.	n.d.
M08-NORM-MP	S-MEAF08-18az	n.d.	n.d.	n.d.
	18bz	n.d.	n.d.	n.d.
CASSINO				
M08-S-CAS-Moac-1	S-MEAF08-19az	n.d.	n.d.	n.d.
	19bz	n.d.	n.d.	n.d.
M08-S-CAS-Moac-2	S-MEAF08-20az	n.d.	n.d.	n.d.
	20bz	n.d.	n.d.	n.d.
GRAVEL PIT				
M08-S-GP-Moac-1	S-MEAF08-21az	n.d.	n.d.	n.d.
	21bz	n.d.	n.d.	n.d.

n.d.: not detected

All dinitrotoluenes, nitrotoluenes, 1,3,5-trinitrobenzene, 1,3-dinitrobenzene and tetryl were not detected in any sample

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Annex A

FILES ATTACHED ON COMPACT DISK

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List of symbols/abbreviations/acronyms/initialisms

ASQG	Agricultural Soil Quality Guideline
BG	Background Sample
BGL	Background Level
CBO	Canadian Base Operators
CCME	Canadian Council of Ministers of the Environment
CFB	Canadian Forces Base
CRREL	Cold Regions Research and Engineering Laboratory
DCC	Defence Construction Canada
DGE	Director General Environment
DLE	Director Land Environment
DND	Department of National Defence
DOD	Department of Defense
DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
EL	Environmental Laboratory
EM	Energetic Materials
ERDC	Environmental R&D Center
GPS	Global Positioning System
HPLC	High Pressure Liquid Chromatography
ICP/MS	Inductively Coupled Plasma /Mass Spectrometry
INRS	Institut national de la recherche scientifique
ISQG	Industrial Soil Quality Guideline
LFC	Land Force Command
LFCA TC	Land Force Central Area Training Centre
MRTA	Meaford Range Training Area
MTSCM	Militia Training and Support Centre Meaford
NDHQ	National Defence Headquarters
OB/OD	Open Burning/Open Detonation
PAH	Polycyclic Aromatic Hydrocarbons

ppb	Parts per billion
ppm	Parts per million
QA/QC	Quality Assurance/ Quality Control
R&D	Research & Development
S	Soil Sample
SERDP	Strategic Environmental R&D Program
TTCP	The Technical Cooperation Program
UXO	Unexploded Ordnances

DOCUMENT CONTROL DATA		
(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)		
1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's report, or tasking agency, are entered in section 8.) Defence R&D Canada – Valcartier 2459 Pie-XI Blvd North Quebec (Quebec) G3J 1X5 Canada	2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.) <u>UNCLASSIFIED</u>	
3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.) Surface soil characterization of explosives and metals at the Land Force Central Area Training Centre (LFCA TC) Meaford, Ontario (Phase II) Final report		
4. AUTHORS (last name, followed by initials – ranks, titles, etc. not to be used) Ampleman, G.; Thiboutot, S.; Marois, A.; Gagnon, A.;		
5. DATE OF PUBLICATION (Month and year of publication of document.) October 2009	6a. NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.) 68	6b. NO. OF REFS (Total cited in document.) 0
7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.) Technical Report		
8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.) Defence R&D Canada – Valcartier 2459 Pie-XI Blvd North Quebec (Quebec) G3J 1X5 Canada		
9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.) 12 So 04	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)	
10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.) DRDC Valcartier TR 2009-218	10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)	
11. DOCUMENT AVAILABILITY (Any limitations on further dissemination of the document, other than those imposed by security classification.) Unlimited		
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This work describes the second evaluation of the impacts of the live fire training at the Land Force Central Area Training Centre (LFCA TC) Meaford, Ontario (Phase II). This study was conducted in August 2008 by DRDC Valcartier for Director Land Environment (DLE) to complete the evaluation of the soil contamination by explosives and metals. In parallel, the Institut national de la recherche scientifique (INRS) conducted sampling and analysis of surface water and groundwater for metals and explosives and produced two separate reports describing the results from their Phase I and II. In our study, most of the ranges at LFCA TC Meaford were sampled during the September 2007 campaign. In August 2008, nine ranges were sampled to complete our understanding of the explosives and/or metals contamination. More precisely, the Apeldorn grenade range was re-visited to confirm metal concentrations observed during Phase I, the Caen range was re-sampled to confirm propellant residues concentrations while Cambrai target positions were re-sampled to examine the high selenium concentrations found during Phase I. In Cassino, small arms target positions were evaluated for metal concentrations while the 40 mm impact area was evaluated for energetic concentrations. The urban assault portion of Ortona range was sampled for energetics while Normandy, Position 409 and the Gravel Pit were sampled for energetics and metals. Finally, it was not possible to sample the stop butt of the impact area. Forty one soil samples were collected and analysed, including 21 for energetic materials, 20 for metals and one for perchlorate analyses. The 20 soil background samples taken for the metals evaluation during Phase I served again for comparison purposes. Metal analyses were done using Inductively Coupled Plasma /Mass Spectrometry (ICP/MS) and explosives concentrations were determined using the High Pressure Liquid Chromatography (HPLC) Method EPA 8330b. The results confirmed that the firing positions of Caen are contaminated by nitroglycerine and 2,4- DNT. Surprisingly, the tank positions in Cambrai still highly contaminated by metals did not show selenium at extreme concentrations as in Phase I. Except for the firing positions in Caen, no energetic materials were detected in any of the samples collected. The Apeldorn grenade range still showed high zinc concentrations as for the Gravel Pit that showed many metal concentrations higher than the Canadian Council of Ministers of Environment (CCME) Industrial Soil Quality Guideline threshold criteria. This report describes the sampling and the results obtained during this study, examines the results obtained during both phases and proposes recommendations for the sustainability of the training areas.

Ce travail décrit la seconde évaluation des impacts de l'entraînement de tir réel faite au Centre d'instruction du Secteur du Centre de la Force terrestre (CISCFT) à Meaford, en Ontario (Phase II). Cette étude a été effectuée en août 2008 par RDDC Valcartier pour le Directeur Environnement de la Force Terrestre (DEAT) afin de compléter l'évaluation de la contamination des sols par les explosifs et les métaux. En parallèle, l'Institut national de la recherche scientifique (INRS) a effectué l'échantillonnage de l'eau de surface et de l'eau souterraine pour les métaux et les explosifs et produit deux rapports séparés décrivant les résultats de leurs phases I et II. Dans notre étude, la plupart des secteurs du CISCFT Meaford ont été échantillonnés pendant la campagne de septembre 2007. En août 2008, neuf secteurs ont été échantillonnés pour compléter l'évaluation de la contamination par les explosifs et/ou par les métaux. Plus précisément, le secteur de grenade Apeldorn a été revisité pour confirmer les concentrations en métaux observées durant la phase I, le secteur Caen a été ré-échantillonné pour confirmer les concentrations de résidus de propulsifs pendant que les positions des cibles de Cambrai ont été ré-échantillonnées pour examiner les concentrations importantes de sélénium observées durant la phase I. Dans Cassino, les positions des cibles de petit calibre ont

été évaluées pour les concentrations en métaux tandis que l'aire d'impact des munitions de 40mm a été évaluée pour les concentrations en matériaux énergétiques. La portion d'assaut urbaine d'Ortona a été échantillonnée pour les énergétiques alors que Normandy, la position 409 et la réserve de pierre concassée ont été échantillonnées pour les concentrations en énergétiques et en métaux. Finalement, il n'a pas été possible d'échantillonner la butte d'arrêt de la zone d'impact. Quarante et un échantillons de sol ont été recueillis et analysés, incluant 21 pour les matériaux énergétiques, 20 pour les métaux et un pour les perchlorates. Les 20 échantillons de sols d'arrière-plans recueillis durant la phase I ont servi de nouveau pour analyser les métaux et servir de comparaison. Les analyses de métaux ont été effectuées par plasma inductif couplé/spectrométrie de masse (PIC/SM) et les concentrations d'explosifs ont été déterminées par la méthode de chromatographie liquide haute pression (CLHP) EPA 8330b. Les résultats ont confirmé que les positions de tir de Caen sont contaminées par de la nitroglycérine et du 2,4-DNT. Étonnamment, les positions des chars d'assaut dans Cambrai toujours très contaminées par des métaux n'ont pas montré les concentrations importantes de sélénium observées durant la phase I. À l'exception des positions de tir dans Caen, aucun matériau énergétique n'a été détecté dans aucun des échantillons ramassés. Le secteur de grenade Apeldorn a encore montré des concentrations de zinc élevées ainsi que le secteur de pierre concassée qui a montré des concentrations à des valeurs supérieures au critère de niveau industriel pour les risques à la santé humaine du Conseil canadien des ministres de l'Environnement (CCME) pour plusieurs métaux. Ce rapport décrit l'échantillonnage utilisé ainsi que les résultats obtenus durant cette étude, examine les résultats obtenus durant les deux phases et propose des recommandations pour le développement durable de ces aires d'entraînement.

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characterization, explosives, soil, metal, contamination

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